A Case Study: Fallacies in ANSI/ISEA 107, 2010 High Visibility Safety Clothing Standard

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Introduction

Detectable distance of some safety vests not compliant to ANSI/ISEA 107 207 standards, has been proved detectable no less than that of conformed. The safety effect of high visibility safety clothing shall be determined by field study, statistic analysis and scientific rules. This report is to illustrate that certain high visibility clothing, including a high visibility clothing tested by SGS, with coefficient of retroreflection not conforming with ANSI/ISEA 107 but do perform equal or better in the safety aspects.

Field Test

In UTMRI 2003-29, CWZ report, HIGH-VISIBILITY SAFETY APPAREL AND THE NIGHTTIME CONSPICUITY OF PEDESTRIANS IN WORK ZONES, it states,
"Retroreflective Trim Intensity: The manipulation of trim intensity did not produce a significant difference in garment conspicuity, despite a rather substantial manipulation. Retroreflective trim that was presented as manufactured (i.e., new materials) was not substantially more conspicuous than retroreflective trims having intensities below 20% of the new materials. While the mean detection distances differed in the direction one might expect, the magnitude of the change was extremely small (about 3% collapsed across all other conditions)."

Coefficient of Retro Reflection (R_A)

The measured coefficient of retroreflection as specified must able to represent the safety function of the retroreflective material. In ANSI/ISEA 107, 2010, table 4 and 5, minimum Coefficient of Reflections are specified in 32 positions in four

(4) observation angles, four (4) entrance angles and for 0^o and 90^o axes, as shown in Table 1.

Table 1 -- Coefficient of reflection (R_A) in $cd.lx^{-1}m^{-2}$ based on the " Standards", ANSI/ISEA 107, 2010, Table 4

Coefficient of Reflective Index (R_A) ($cd.lx^{-1}m^{-2}.$)				
Observation Angle	Entrance Angle			
	5°	20°	30°	40°
12′	330	290	180	65
20′	250	200	170	60
1°	25	15	12	10
1°30′	10	7	5	4

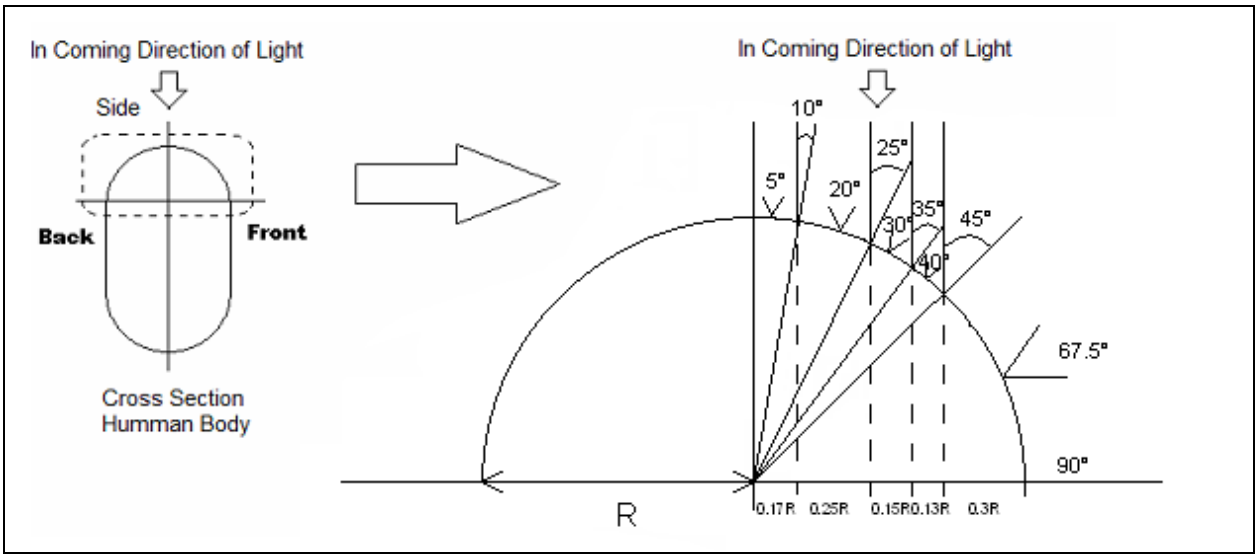
Observation Angle is the angle between the line from the light source to reflective fabric and the line from the reflective fabric to the driver's eyes. Considering there is a distance from the driver's eye level to the light source (d), the required coefficient of retoreflection (R_A) for each of observation angle (OA) is related to and proportional to the detection distance (D). $OA = \tan^{-1}(d/D)$. The eye to lamp distance (d) varies depend on type of vehicles. But the observation angle are not correspond to the critical detection distance for drivers in different sizes of vehicles

Entrance Angle is the angle between the incoming light and the line perpendicular to the plane of the reflective fabric surface. What drivers observed in any observation distance is a collection of light reflected from every part of reflective material with different entrance angles.

The entrance angles specified in ANSI/ISEA 107standards are 5^o, 20^o, 30^o, and 40^o. Since the above angles are not evenly distributed, it is reasonably to divide the reflective material that each angle representing an area such as that 5^o: 0^o-10^o, 20^o: 10^o – 25^o, 30^o: 25^o – 35^o, 40^o: 35^o – 45^o, as plotted in Figure 1. Cross section of the torso of human body is close to an oval shape. Normally the width is larger than the depth. Therefore, observed area of the front view in normal bigger than that of the side view that the least observable view is the side view. Since the clothing is specified to be seen in 360^o, the minimum requirements shall applied to the side view. With the surface of safety clothing normally curved, the reflective fabric facing the driver within 5^o entrance angle is small as shown in the figure 2 below.

Therefore, the coefficient of retroreflection in 32 positions as required in the specification is neither related to critical detection distance to avoid accidents nor representing the function of the reflective material measured.

Figure 1. Projected area of for each specified entrance angle in ANSI/ISEA 107



Source: King Tech Industry, San Diego, California, 2010

Comparison of luminous intensity based on ANSI/ISEA specified Coefficient of Reflection

Since a retroreflective material observed by drivers is the total reflective light collected from the entire reflective material area. Not just from that of the few specific entrance angles as specified. Therefore, specifying a minimum coefficient R_A for each of the entrance angle is not necessary. Because if one of the R_A reading falls short while others are well above, the total luminance intensity is still above the standard. What shall be specified shall be the total luminance or the average of the coefficient of retroreflection.

What the driver observed is a projected area which is smaller than the actual reflective fabric area in a ratio about 1: π/2. The observed reflective area over a human body is in a curve. Looking from the side view it is a hemi cylinder shape as shown in Figure 1. The ratio of each section of projected area to actual area is equal to sin Θ , where Θ is the corresponding average entrance angle for the

section. R_A with 5^o entrance angle representing the ratio of an area between 0^o to 10^o or sin 10^o = 0.17, and the Ra of 20^o, 30^o and 40^o representing the ratio of 0.25, 0.15 and 0.13 respectfully. In ANSI /ISEA 107 standard, for entrance angle bigger than 40^o, R_A is not measured or ignored.

Assuming R_A (a) is R_A of 5^o entrance, R_A (b) is of 20^o entrance angle, R_A (c) is of 30^o entrance angle and R_A (d) is of 40^o entrance angle, that average Ra for each of observation angle is R_A (a) × 0.17 + R_A (b) × 0.25 + R_A (c) × 0.15 + R_A (d) × 0.13.

As shown in table 4, a reflective fabric from a sample clothing been tested by SGS, report number SH01049694/TX., the reflective fabric does not meet ANSI/ISEA 107/207, 2010 standard.

Because the luminous intensity (I) is equal to coefficient of retroreflection times the area the reflective fabric. A comparison of the average coefficient of reflection between what specified in ANSI/ISEA 107, level 1 / level 2 and the SGS tested data are:

The average coefficient ofReflective index for required ANSI/ISEA 107/207, level 2, for each observation angles are:

Observation angle 12′
R_A =330×0.17+290×0.25+180×0.15+65×0.13=164.05 $cd.lx^{-1}m^{-2}$
Observation angle 20′
R_A =250×0.17+200×0.25+170×0.15+60×0.13=125.8 $cd.lx^{-1}m^{-2}$
Observation angle 1°
R_A =25×0.17+15×0.25+12×0.15+10×0.13=11.1 $cd.lx^{-1}m^{-2}$
Observation angle 1 .5°
R_A =10×0.17+7×0.25+5×0.15+4×0.13=4.72 $cd.lx^{-1}m^{-2}$

And the average Reflective index for required ANSI/ISEA 107/207, level 1, for each observation angles are:
Observation angle 12′
R_A =250×0.17+220×0.25+135×0.15+50×0.13=124.25 $cd.lx^{-1}m^{-2}$
Observation angle 20′
R_A =120×0.17+100×0.25+75×0.15+30×0.13=60.55 $cd.lx^{-1}m^{-2}$
Observation angle 1°
R_A =19×0.17+11×0.25+9×0.15+7×0.13=8.24 $cd.lx^{-1}m^{-2}$
Observation angle 1 .5°
R_A =7×0.17+5×0.25+3×0.15+3×0.13=3.28 $cd.lx^{-1}m^{-2}$

Average R_A of the SGS tested data, for each observation angles are:
Observation angle 12′
R_A =227×0.17+256×0.25+285×0.15+282×0.13=182 cd.lx^{-1}m^{-2}
Observation angle 20′
R_A =180×0.17+196×0.25+212×0.15+230×0.13=141.3 cd.lx^{-1}m^{-2}
Observation angle 1°
R_A =23.5×0.17+26.2×0.25+29.1×0.15+23.5×0.13=17.965 cd.lx^{-1}m^{-2}
Observation angle 1 .5°
R_A =15.3×0.17+15.2×0.25+17.4×0.15+18.9×0.13=11.468 cd.lx^{-1}m^{-2}

The average Ra of the reflective material as in the SGS report is higher than both of that in ANSI/ISEA 107, level 1 and level 2. Therefore, the reflective fabric as in the SGS report is more visible than that of ANSI/ISEA 107/207, 2010 specified. The comparison is as in table 3.

Table 3, Average Coefficient of Retroreflection, Ra: Comparison of a sample reflective fabric tested by SGS with reflective material specified in ASNI/ISEA 107/207, 2010.

	level 2	level 1	SGS
12'	164.05	124.25	182
20'	125.8	60.55	141.3
1°	11.1	8.24	18
1°30′	4.7	3.3	11

Table 4, SGS report of a reflective materal tested based on ANSI/ISEA 107, 2010 specification

SGS

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Test Result

American National Standard for High-Visibility Safety Apparel and Headwear (ANSI/ISEA 107-2010)

Retroreflective Material Testing Report, Level 1

PHOTOMETRIC PERFORMANCE REQUIREMENTS					
Take measurements at $\varepsilon_1 = 0^\circ$ and $\varepsilon_2 = 90^\circ$. Record maximum value on left side of test result column and the other value on right side of test result column.					
ANSI/ISEA 107 Requirement Section 8.1, Table 5			Test Result cd/(lx·m^2)		Pass/ Fail
Observation Angle	Entrance Angle	Minimum cd/(lx·m^2)			
12' (0.2°)	5°	250 / 187.5	227	217	Fail
	20°	220 / 165	256	251	Pass
	30°	135 / 101.25	285	283	Pass
	40°	50 / 37.5	282	264	Pass
20' (0.33°)	5°	120 / 90	180	164	Pass
	20°	100 / 75	196	189	Pass
	30°	75 / 56.25	212	206	Pass
	40°	30 / 22.5	230	220	Pass
1.0°	5°	19 / 14.25	23.5	22.9	Pass
	20°	11 / 8.25	26.2	24.5	Pass
	30°	9 / 6.75	29.1	27.7	Pass
	40°	7 / 5.25	23.5	22.6	Pass
1.5°	5°	7 / 5.25	15.3	13.8	Pass
	20°	5 / 3.75	15.2	14.9	Pass
	30°	3 / 2.25	17.4	17.2	Pass
	40°	3 / 2.25	18.9	18.3	Pass

This test was carried out by SGS HK textile lab.

Comparison of design based on ANSI/ISEA recommendation

In the side view of a person, there is always an arm blocking part of reflective material in Class 1 and Class 2 safety clothing. And the part been covered happen to be the center part where the entrance angles are within 40°. In ANSI/ISEA 107/207 specifications, the entrance angle are specified up to 40° angle, reflectivity in the part over 40° was neglected; the overall observed brightness is nil. Therefore, all Class 1 and Class 2 safety garment as specified in ANSI/ISEA 107/207 do not meet the 360° visibility requirement in the same standard. See figure 2 as below:

Figure 2 – Illustrated Occupational Safety Vest, the "Standards" Class 2

Source: King Tech Industry, San Diego, California, 2010.

For Class 3 clothing, disregard whatever the total reflective area required in the standard, the only visible part is on the arms, a 2" width stripe with no more than 5" length within 40^{o} .entrance angle. The effective reflective area is only 10 si .

What drivers can see as "brightness" or luminance, is measured as Luminous Intensity (I), in candelas per square meter ($cd.m^{-2}$), Luminous Intensity (I) equals to Ra times the area of retroreflective material. $RI = R_A \times A$

At observation angle of 12", which is the critical detection distance of 140m:

For ANSI/ISEA 107 Class 3 level 2 clothing, the luminance intensity is:

$RI = R_A \times A = 164\ cd.lx^{-1}m^{-2} \text{ X } 10\ si = 1.06\ cd.lx^{-1}$

For ANSI/ISEA 107 Class 3 level 1 clothing, the luminance intensity is:

$RI = R_A \times A = 124\ cd.lx^{-1}m^{-2} \text{ X } 10\ si = 0.80\ cd.lx^{-1}$

None ANSI material as in the SGS report in table 4

$RI = R_A \times A = 184\ cd.lx^{-1}m^{-2} \times 40\ si = 4.74\ cd.lx^{-1}$

Therefore the luminous intensity of the clothing design as in figure 3, and the reflective material in the SGS report, not in conform with ANSI/ISEA 107 standard, is far brighter than those conformed. The design offers similar size of effective retroreflective area in both horizontal view and vertical view in all direction, the minimum effective reflective area is measured over 40 ^{si} in every viewing angle. The Luminous Intensity of this clothing is proofed far above that that of specified in ANSI/ISEA 107.207.

Figure 3 – High Visibility Safety Clothing, Silhouette Safety T-Shirt

Source: King Tech Industry, San Diego, California, 2010.

Conclusion

The results of this study show the specification as in ANSI/ISEA 107 standard does not properly identify appropriate functions for high visibility safety clothing. Clothing that are recommended by the standard does not meet the safety requirement of the same standard, while clothing that can produce sufficient levels of conspicuity are excluded from use.

Class 1 and Class 2 safety clothing as recommended in ANSI/ISEA 107/207standard, does not meet the 360^{o} visibility requirement in the same standard 6.1.6. They are totally invisible in the side view at dark as in figure 2.

The minimum values of retroreflective index as specified in the standard are not the actual minimum requirement to achieve the necessary conspicuity. However, the required values of the coefficient of retroreflection are not included or excluded in the standard.

The entrance angles as specified in the ANSI/ISEA 107/207standard, 5^{o}, 20^{o}, 30^{o}, and 40^{o}, do not full represent the function of the reflective material.

The observation angles as specified in the ANSI/ISEA 107/207standards are not related to the critical detection distance and luminous Intensity at the distance. The critical distance is the distance at the critical time when the driver must see the object to avoid accidents. Therefore, ANSI/ISEA 107/207 standards are not based on safety requirements as described by Scandinavian Report, Morkertrafik, Night Traffic Rapport, NR. 5, and The University of Michigan Transportation Research Institute report, UMTRI I-98-50.